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(71) Applicant: **APPLIED MATERIALS, INC.**
3050 Bowers Avenue
Santa Clara California 95054-3299(US)

(72) Inventor: **Turner, Norman L.**
1207 Christobal Privada
Mountain View, CA 94040(US)
Inventor: **White, John Macneill**
2811 Colony View Place
Hayward, CA 94541(US)

(74) Representative: **Bayliss, Geoffrey Cyril et al**
BOULT, WADE & TENNANT
27 Furnival Street
London EC4A 1PQ (GB)

(54) **Vacuum Processing apparatus having improved throughput.**

(57) The disclosure relates to a method for depositing sequential thin films on glass substrates by single substrate deposition comprising loading a batch of substrates into a load lock chamber and evacuating the chamber, transferring the substrates to a batch heating chamber for heating the substrates to elevated temperatures; transferring the glass substrates singly to one or more single substrate processing chambers, and sequentially transferring the substrates back to the load lock chamber where they are batch cooled.

The disclosure also relates to a vacuum system for carrying out the method includes a load lock/cooling chamber (14A, 14B) for evacuating a plurality of glass substrates; a heating chamber (28) for heating a plurality of substrates to elevated temperatures; one or more single substrate processing chambers (40, 42, 44, 46); and a transfer chamber (12) having access to all of said chambers and having automated means (22) therein for transferring the glass substrates into and out of said chambers in a preselected order.

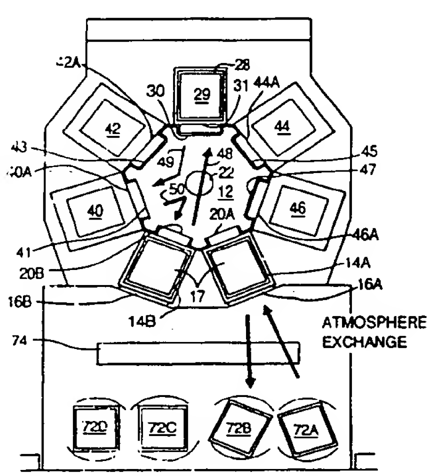

Fig. 1

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This invention relates to a vacuum system for deposition of multiple thin films in single substrate processing chambers. More particularly, this invention relates to a vacuum system that combines single substrate processing chambers with batch heating and cooling chambers.

Liquid crystal cells for active matrix TV and computer monitors are made of two glass plates sandwiching a layer of liquid crystal material between them. The glass plates are made conductive with a thin conductive film on the inside faces of the plates so that a source of power may be connected to them for changing the orientation of the liquid crystal molecules. As the need for larger and more sophisticated cells that allow separate addressing of different areas of the liquid crystal cell has progressed, as for active matrix TV where up to 1,000,000 or more different areas or pixels need to be separately addressed, the use of thin film transistors for this application has come into widespread use. Thin film transistors comprise a patterned metal gate over which is deposited a gate dielectric layer and a conductive layer, such as amorphous silicon. Subsequently applied layers, as of doped amorphous silicon, etch stopper silicon nitride, silicon oxide, metal contact layers and the like, are also required to be deposited over the amorphous silicon thin film. Many of these films are deposited by CVD in order to obtain high quality films.

In the semiconductor industry, as substrates such as silicon wafers have become larger, permitting a greater number of devices to be formed on a wafer, single substrate processing has largely replaced batch type processing of several wafers at a time. Single substrate processing allows greater control of the process, permits smaller vacuum chambers to be used and, if a problem arises during processing, only a single wafer, rather than a whole batch of wafers, is damaged or lost.

To improve the productivity of a single substrate vacuum processing system, including evacuating and re-pressurizing the processing chamber after each substrate has been processed, vacuum equipment has been designed that includes more than one processing chamber and a transfer chamber, so that multiple step processes can be performed in different chambers on a single substrate without removing the substrate from a vacuum environment. Such a system also has the concomitant advantage of a cleaner system. For example, Maydan et al have disclosed such a system in US Patent 4,951,601, which comprises a central transfer chamber surrounded by and connected to various processing chambers. A robot in the transfer chamber transfers the substrates from one chamber to another. The elimination of the need for evacuating the chambers prior to each processing step by the addition of a vacuum load lock also increases the throughput of the equipment.

Glass is a brittle dielectric material that requires slow heating and cooling, e.g., about 5 minutes or more, to avoid cracking or stressing of large glass plates over the temperature range of from room temperature up to about 300-450 °C, typically used for vacuum processing. Since the actual thin film deposition requires only seconds, without special provisions being made, a lot of idle time in the vacuum system would occur while the substrates are being individually heated and cooled. This waiting time would be very costly in terms of lost reactor time, and thus deposition of films in single substrate chambers would not be economical.

The deposition of multiple layer films on single glass substrates in a single vacuum system has been disclosed for example by Gallego, US Patent 4,592,306. The vacuum system disclosed by Gallego includes four or more deposition chambers connected to a central transfer chamber, a loading chamber and an exit chamber. Substrates are loaded into the system in the loading chamber which is evacuated, and the substrate is transferred by means of a robot in the central transfer chamber successively to two or more deposition chambers where various layers are deposited. The exit chamber can double as a metal deposition chamber. The sequential thin films are deposited onto the substrates which are loaded in the deposition chambers one at a time. The system was designed for sequentially depositing intrinsic and doped amorphous silicon layers for the manufacture of solar cells. Deposition is by glow discharge of silane and suitable dopant gases.

This system, while effective to deposit sequential layers on large glass substrates in a single vacuum system without breaking vacuum, is uneconomic because of the long period of time required to process each substrate and it does not provide heating and cooling of substrate materials. Gallego addresses part of this problem by providing two chambers for the deposition of intrinsic amorphous silicon, which layer is thicker and thus requires a longer deposition time than the thinner, doped amorphous silicon layers. However, Gallego did not address ways of reducing the overall deposition time or how to bring the temperature of the substrates to the reaction temperature, (270 °C) nor the time required to cool the substrates back to ambient temperatures prior to removing the substrate from the vacuum system.

Thin film transistors cannot be made using glow discharge techniques since amorphous silicon films made by glow discharge of silane have a high hydrogen content, which makes for unstable films and thus unstable transistor devices. Since CVD processes require higher temperatures than glow discharge deposition, on the order of 350-450 °C, and the glass substrates useful for active matrix TV monitors

The arrows 48, 49 and 50 respectively show the direction of transfer for one possible sequence; arrow 48 shows the direction of transfer from the load lock/cooling chamber 14B to the heating chamber 28; arrow 49 shows the direction of transfer of a substrate from the heating chamber 28 to a CVD chamber 40; and the arrow 50 shows the direction of transfer of a substrate from the CVD chamber 40 back to the load lock/cooling chamber 14B until the load lock is fully exchanged; then when the chamber 14B is venting to atmosphere, load lock chamber 14A is available to the vacuum robot so that continuous processing is provided.

Details of the heating and cooling chamber cassettes 15 and 27 are shown in Fig. 2, which is a cross sectional view of a cooling chamber cassette 17.

The shelves 60 in both the heating chamber cassette 29 and the load lock/cooling chambers cassettes 17 are made of a heat conductive material such as stainless steel clad copper, nickel coated stainless steel and the like. The side walls 62, 64 of the cassettes 17 and 29 are also made of a heat conductive metal, such as aluminum or copper. A channel 66 in the sidewalls 62, 64 of the cassette 29 contain a resistive heater connected to a source of power. A channel 68 in the sidewalls of the cooling chamber cassettes 17 permit the circulation of a coolant, such as water or other liquid, built into the sidewalls 62, 64 of these chambers. The glass substrates are situate on a plurality of dielectric mounts 70 which are situate or affixed onto the shelves 60 so that there is a gap between the substrates and the shelves 60. The glass substrates are thus radiantly heated or cooled uniformly from both sides, which provides for rapid and uniform heating or cooling and prevents cracking or warping of the substrates, even when heating or cooling over a temperature range of about 400 °C.

After the substrates have been placed in the cooled cassette 17, cooling starts and after the loading time and chamber venting time has elapsed, the glass substrates are cool and the substrates can be removed from the vacuum system 10 through the load door 16A in the outer wall and stacked onto suitable storage cassettes 72.

The glass substrates can be loaded into the vacuum system 10 manually or in automated fashion. As shown in Fig. 1, a commercially available robot 74 mounted on a rail frame outside the vacuum system 10 at a first station opposite the load lock chamber 14A can retrieve a glass substrate from an empty storage cassette 72A, and load the glass substrates one at a time into the vacuum system 10 via the load lock/cooling chamber 14A. When the chamber 14A is filled and closed, the robot 74 can slide along the rail to a second station opposite the load lock chamber 14B and proceed to fill the second load lock/cooling chamber 14B, as from the cassette 72C. At the end of processing of the first load of substrates, the robot 74 can retrieve the processed substrates from the load lock chamber 14A and place the now coated substrates into an empty cassette 72B.

While the first batch of substrates are being processed and reloaded into a cassette in the first load lock/cool chamber 14A, a second batch of substrates can be loaded and brought down to vacuum in a cassette in the second, like load lock/cooling chamber 14B. Thus while the first batch of substrates is being cooled and removed from the vacuum system 10, a second batch of substrates has been brought to vacuum, heated and is now available for processing among the CVD chambers 40, 42, 44 and 46. The presence of two load lock chambers ensures a continuous processing of substrates in the vacuum system 10.

For the manufacture of thin film transistors onto large glass substrates, the average time for loading a glass substrate into and unloading it out of a load lock/cooling chamber is about 15 seconds for each operation, whereas the average time for heating a glass substrate to film deposition temperature is about 300 seconds. By having a batch of preheated glass substrates waiting their turn for processing or venting back to atmosphere, the long average heating time for a substrate is hidden in the waiting time for processing or venting respectively.

Thus the system 10 provides continuous and rapid processing of substrates by performing the lengthy heating and cooling steps in a batch-type chamber; and it provides for processing substrates in the processing chambers one at a time, thus retaining all the advantages of such single substrate processing. Further, combining a load lock function and a cooling function in a single cooling/load lock chamber eliminates the need for an additional cooling chamber and an additional transfer of the substrates, which further adds to the efficiency of the present vacuum system.

Although the present vacuum system has been illustrated using certain embodiments and sequences, various changes can be made to the equipment without departing from the essence of the invention. For example, various numbers of processing, heating and cooling chambers or combined heating and cooling chambers can be employed providing they are accessible to the central transfer chamber; various sequences of heating, deposition and cooling can be carried out depending upon the thin films and sequences of deposition desired; and additional processing chambers can be added or substituted in the

system, such as physical vapor deposition or etch chambers, preclean chambers and the like. Such variations and changes will be apparent to one skilled in the art, and the invention is only meant to be limited by the appended claims.

Claims

1. A vacuum system for single substrate film processing onto glass substrates comprising:
   one or more load lock/cooling chambers having a plurality of shelves for supporting and cooling a plurality of glass substrates therein;
   a heating chamber for heating a plurality of glass substrates to elevated temperatures;
   one or more single substrate processing chambers for deposition of thin films onto said glass substrates, and
   a transfer chamber having access to all of said chambers and having automated means of transferring glass substrates to any of said chambers.

2. A vacuum system according to claim 1, wherein said load lock/cooling and heating chambers contain cassettes that are mounted on an elevator assembly.

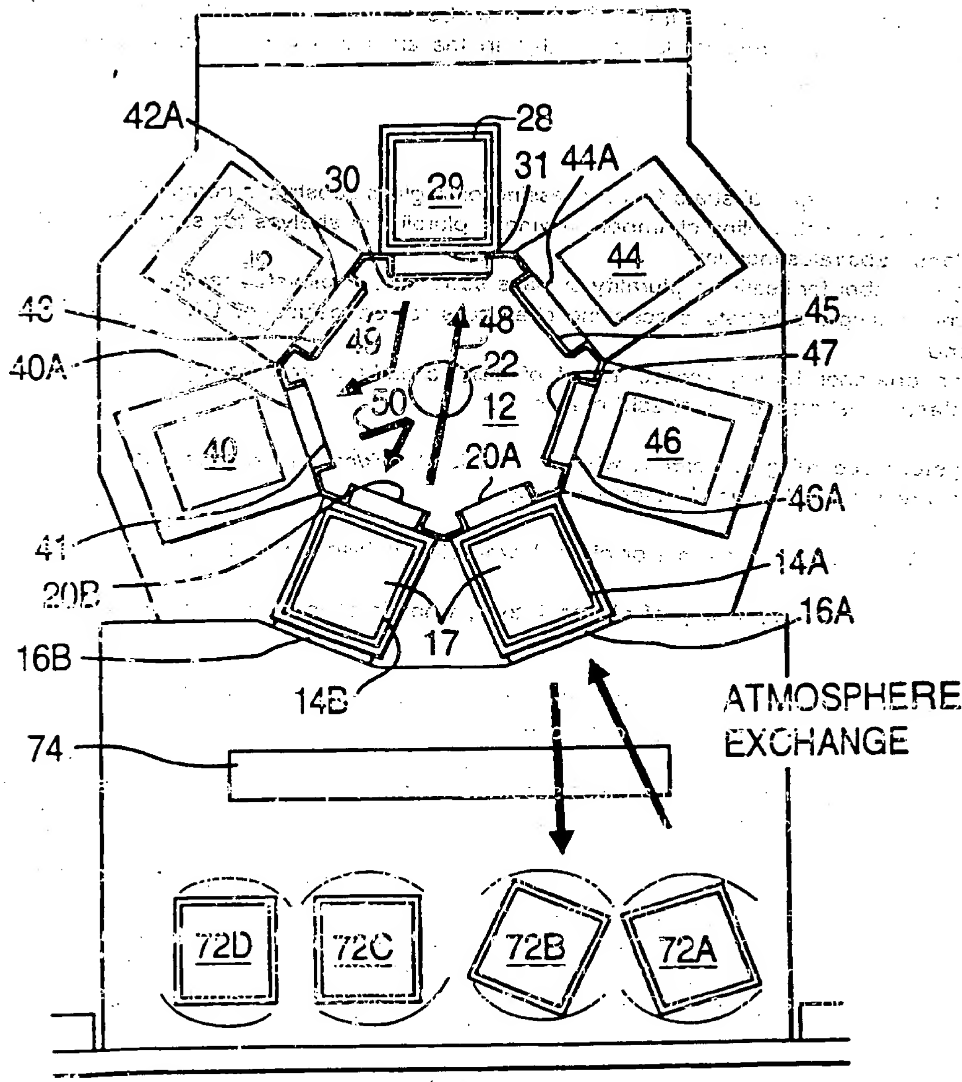
3. A vacuum system according to claim 1 or claim 2, wherein two load lock/cooling chambers are present.

4. A vacuum system according to any of claims 1 to 3, wherein at least two processing chambers are present.

5. A vacuum system according to any of claims 1 to 4, wherein said single substrate processing chambers are chemical vapor deposition chambers.

6. A method of depositing thin films onto a glass substrate which comprises the steps in sequence:
   a) loading a plurality of glass substrates into a load lock/cooling chamber and evacuating said chamber;
   b) transferring all of said glass substrates through a connecting vacuum transfer chamber to a chamber adapted for heating said substrates to elevated temperatures;
   c) transferring one of the heated substrates from step b) through the transfer chamber to a single substrate processing chamber and depositing a thin film thereon; and
   d) transferring a substrate from step c) back to the load lock/cooling chamber of step a) and cooling the substrate.

7. A method according to claim 6, wherein subsequent to step c) the step of transferring the substrate to one or more additional processing chambers for depositing additional thin films thereon.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14B
ATMOSPHERE
EXCHANGE
74
72D
72C
72B
72A

Fig. 1

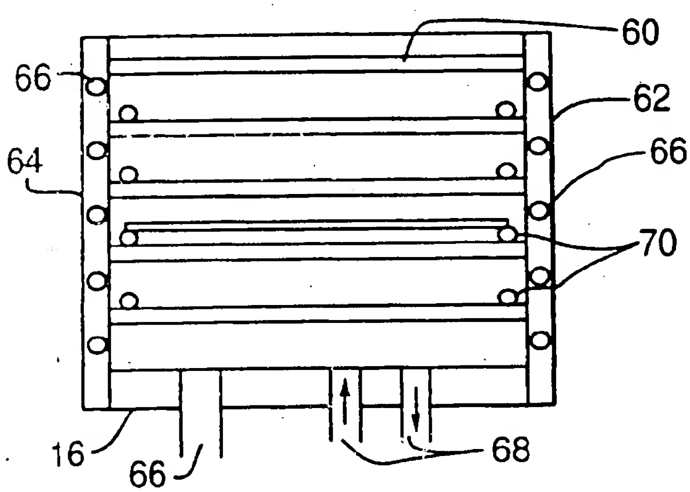
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Fig. 2

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EUROPEAN SEARCH REPORT

Application Number

EP 93310250.1

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE - B - 1 446 199 (LIBBEY-OWENS-FORD GLASS CO.) * Claims 1,4-6 * --	1,4	C 23 C 16/00 C 03 C 17/09
A	US - A - 4 547 247 (WARENBACK et al.) * Claim 1; column 9, lines 24-47 * --	1,2,4, 5	
A	US - A - 3 945 903 (SVENDOR et al.) * Claims 1-4 * --	1	
D,A	US - A - 4 951 601 (MAYDAN et al.) * Claim 1 * --	1-4	
A	US - A - 4 405 435 (TATEISHI et al.) * Claim 1 * --	1,2,4	
A	US - A - 5 076 205 (VOWELS et al.) * Claim 1 * --	1,4,5	TECHNICAL FIELDS SEARCHED (Int. Cl.5) C 03 C 17/00 C 23 C 14/00 C 23 C 16/00 H 01 L 21/00
D,A	US - A - 4 592 306 (GALLEGO) * Claim 1 * --	1,5,7	
P,A	EP - A - 0 525 202 (SEMICONDUCTOR PROCESS LABORATORY CO. LTD. & CANON SALES CO. INC. & ALCAN-TECH CO. INC.) * Claim 1; abstract *	1,5	
A	& WO-A-92/15 116 ----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	28-04-1994	PUSTERER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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